REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
14/03/2006	Final	3/30/2004 - 8/31/2005

4. TITLE AND SUBTITLE
Video Games as a Tool to Train Cognitive Skills

5a. CONTRACT NUMBER

5b. GRANT NUMBER
N00014-04-1-0364

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Bavelier, Daphne

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
University of Rochester
518 Hylan Building
Rochester, New York 14627

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Ballston Centre Tower One
800 North Quincy Street
Arlington, VA 22217-5660

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The general goals and aims of this project were to evaluate the use of computer training software, and in particular action video games, as a tool to train and enhance perceptual skills, visual attention and working memory capacities.

15. SUBJECT TERMS
video games, perceptual skills, visual attention, working memory

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Charlene Sinclair
U	U	U	UU	5	19b. TELEPHONE NUMBER *(Include area code)* 585-275-5776

Video Games as a Tool to Train Cognitive Skills

START DATE: March 30th, 2004
REPORT DATE: March 10th, 2006

REPORT STATUS: SUMMARY OF RESEARCH ACTIVITIES

Institution
University of Rochester (The College)
Rochester, NY 14627

Principal Scientist
Daphne Bavelier, Ph.D.
Department of Brain and Cognitive Sciences
Meliora Hall, 0268
University of Rochester
Rochester NY 14627

Phone: (585) 275-8714
FAX: (585) 442-9216
Email: daphne@cvs.rochester.edu

GENERAL GOALS AND AIMS. Evaluate the use of computer training software, and in particular action video game, as a tool to train and enhance perceptual skills, visual attention and working memory capacities. Our previous work has shown that playing just 10 hours of an action video game leads to mark improvement in the number of objects that can be attended, the amount of visual information that can be processed in a fast stream of visual information and the ability to search and locate targets in a cluttered visual scene (Green and Bavelier, Nature, 2003). The studies described below build up on this work.

STUDY ONE. Evaluation of the Interactive Metronome as a training tool for visual attention and working memory – Staff/Coordinator: Julie Cohen (IM contact is Bruce Odle).

Goal. Evaluate IM training as a way to enhance visual attention and working memory.

Method.: Seventy two participants were included in a training study. Participants performance was evaluated before and after training on four tests developed to assess the ability (i) to develop attention over space (Useful Field Of View test), (ii) to process fast occurring visual information (Attentional Blink test), (iii) to monitor several objects at once (Moving Object Tracking test) and (iv) to hold an manipulate information in one's mind (Ospan test).

To further characterize the components of training that enhance visual selective attention, we compared the IM training to four video games that are representative of four popular genres. Training games were selected so as to place different demands on temporal and capacity-related aspects of visual selective attention, that is, they differ from one another in terms of game speed, the number of objects that must be kept track of during the course of the game and the frequency, speed and precision of responses required from players. The Interactive Metronome rhythmicity-training paradigm was used in addition to commercial games in order to examine the effects of training that places very high demands on timing skills and motor coordination while being otherwise very unlike typical video game play. The training groups were as follows: *Group #1* - played a standard first-person action game (Unreal Tournament 2004); *Group #2* - played a slower-paced, team-based, first-person shooting game (America's Army); *Group #3* - played a fast, first-person, multi-ball sport game (Harry Potter: Quidditch World Cup); *Group #4* - played a speeded visuo-motor puzzle game (Tetris); *Group #5* - received rhythmicity training (Interactive Metronome); and the *Baseline Group* - played a set of basic computer card games (Solitaire, Free Cell, Hearts and Minesweeper).

Results. There was no difference between the Tetris trained group and the IM trained group. Overall both group showed a slight test-retest improvement, but unlike what we have found with action video game, IM did not improve post training performance more than Tetris.

This work was presented at the Cognitive Neuroscience Society (New York, NY April 2005). We are in the process of completing a manuscript titled " Training visual attention with video games: Not all games are created equal" by Julie Cohen, Shawn C. Green and Daphne Bavelier to be submitted to the Journal of Experimental Psychology: General.

STUDY TWO. Evaluation of the impact of action game training on the spatial resolution of vision - Staff/Coordinator: Shawn Green

Goal. We have shown that action game training enhances the allocation of visuo-spatial attention. The goal of these studies is to understand the mechanisms that underlie this improvement. We are testing the hypothesis that action game training increase the spatial resolution of vision, meaning that gamers can resolve smaller details in more crowded display.

General Approach. This line of research includes several steps. First we have confirmed that action game player do not just display greater spatial attention in the visual periphery at the cost of central vision. We have done so using a flanker compatibility paradigm. This paradigm provides an indirect measure of spatial attention by measuring the amount of attention irrelevant information (i.e. information that subjects are told to ignore) receives. Second, we have confirmed that gamers have better spatial attention by using a direct measure of attentional resources (visual search task). Third, we

have shown that action gamers are able to resolve better crowded visual information, reflecting a direct increase in the spatial resolution of vision (crowding paradigm). Not only have gamers been compared to non-gamers but training studies have been carried to establish the causal effect of gaming.

Some of this work was presented at the Vision ScienceS conference (VSS, Sarasota, FL, May 2005). We have one paper under review at JEP:HPP titled "Effects of video game playing on the spatial distribution of visual selective attention" and another paper under review at Psychological Science titled "Action video game experience alters the spatial resolution of vision".

STUDY THREE. Evaluation of the impact of action game on the temporal dynamics of lateral interactions in the visual system – Staff/Coordinator: Renji Li in collaboration with Dr. U. Polat (Israel) and Dr. W. Makous (U. of Rochester)

Goal. Characterize as precisely as possible the changes induced by action game training on the temporal properties of visual processing. It has been known for quite some time that detection of an oriented visual target can be facilitated by collinear visual flankers. Such lateral interactions are thought to reflect the integrative architecture of visual receptive fields throughout the visual hierarchy but specially in early visual areas. These receptive field properties are in turn critically determining the temporal dynamics of visual behavior. Our goal is to characterize in detail how action gaming modifies temporal processing in the visual system, and in particular to test the hypothesis that action gamers can extract more visual information from the display in a shorer amount of time than non gamers.

Methods. To assess this issue we have been using two standard protocols to study the temporal dynamics of vision: masking and flicker fusion. The masking experiments are done in collaboration with Dr. Polat. The experimental paradigm has been provided to us by Dr. U. Polat. We have shown that gamers are less affected by masking than nongamers indicating that they can extract stable representations of their visual world faster than non gamers. The flicker fusion experiments are being performed in collaboration with Dr. W. Makous. We have preliminary data indicating that action gamers are able to resolve flickering lights of higher frequency than non gamers indicating a greater temporal resolution of visual processing in these individuals.

These studies will be presented at the Vision ScienceS conference (VSS, Sarasota, FL, May 2006).

STUDY FOUR. Computational models of perceptual learning – Staff/Coordinator: Weiji Ma in collaboration with Dr. A. Pouget (U. of Rochester, USA)

Goal. Develop a quantitative model of a neural architecture that can exhibit learning with the same characteristics as those described in our behavioral studies. This work is done in collaboration with Dr. A. Pouget, an expert in the field of Computational Neurosciences.

Approach/Results. The model focuses on the detection and discrimination of orientation direction as there exists several standard neural network models of orientation selectivity. We ask how perceptual learning can occur in these networks. One challenge is that learning at the behavioral level is observed in the absence of any feedback (subjects do not know whether their performance is correct or not). Thus far, no biologically plausible learning rule were available to perform near-optimal learning under such conditions (for example, the Hebb rule is not optimal for learning in such networks). We have found that a self-supervised version of the delta rule can provide a near optimal solution to this problem, allowing optimal learning without supervision, a first step in providing a biologically plausible model of the behavioral effects we study.

This work was presented at the Cosyne conference (Salt Lake City, March 2005).

STUDY FIVE. Neural bases of perceptual learning - Staff/Coordinator: Rebecca Achtman

Goal. Characterize the neural correlates of the learning induced by video game training. What brain areas change as a result of learning and how do they change?

Approach. We use functional and structural imaging of the brain to tackle this issue. We have access to a 3.0T Trio Siemens, a state of the art magnet dedicated to research. To investigate the effect of playing on the structure of the brain, we have performed a volumetric study, scanning volunteers before and after 30 hours of game training. The goal is to characterize the brain areas that show structural changes, either in grey matter or white matter, as a result of training. Data from all participants have been collected and analysis of this data set is on-going. To investigate the effect of playing on the functional organization of visual skills, we have developed a paradigm that looks at the effect of playing on the dorsal visual pathway, including early visual areas, MT/MST a brain area specialized for motion processing, the parietal cortex and the frontal cortex. Data comparing gamers and non gamers are presently being analyzed.

SUMMARY OF MANUSCRIPT DURING GRANT PERIOD

1- Green, C.S. & Bavelier, D. (In Press). Enumeration versus object tracking: Insights from video game players. Cognition.

This paper shows that action gaming increase the number of objects that can be tracked but not the number of objects that can be subitized. These results indicate that subitizing is really relying on a different mechanism than counting and demonstrate that video game play affects visual short-term memory processes rather than the mechanisms believed to subtend subitizing.

2- Dye, M.G.W & Bavelier, D. (Under Review). Development of visual attention skills in school-age children who play or do not play action video games. Nature Neuroscience.

This paper shows that action game training has very similar effects on children (7-17years old) than on adults and raise the issue of future gender bias when evaluating spatial and attentional skills since boys are much more likely to expose themselves to action games than girls.

3- Green, C.S. & Bavelier, D. (Under Review). Effects of video game playing on the spatial distribution of visual selective attention. Journal of Experimental Psychology: Human Perception and Performance.

This paper shows that action game playing enhances visual selective attention, not only to the periphery but in central vision too. It also demonstrates that gaming facilitates multi-tasking although it does so by enhancing more readily peripheral task performance and only more slowly central task performance.

4- Green, C.S., & Bavelier, D (Under Review). Action video game experience alters the spatial resolution of vision. Psychological Science

This work shows that gamers are able to resolve smaller details in the presence of competing flankers than non gamers. It demonstrates that one of the mechanism by which action game playing enhances visual attention is by increasing the spatial resolution of visual processing.

5- Cohen, J.E., Green, C.S., & Bavelier, D. (To be submitted to JEP:HPP). Training visual attention with video games: Not all games are created equal.

This paper investigates how 6 different types of training (action game, American Army, Tetris, Harry Potter, Interactive Metronome, and Card games) modify the ability to sustain attention over time. Although some training groups showed test-retest improvements, only the action game group was found to improve significantly more than the baseline card game group.

6- Dye, M.G.W., Green, C.S., & Bavelier, D. (In preparation). Specificity of visual attention changes after action game playing: the case of the Attentional Network Task.

This paper shows that although action video game require to monitor abrupt onsets known to readily engage exogenous attention, no changes are observed in the way exogenous attention summons attention in space and time or even allow to filter irrelevant information. This lack of effect was observed in children and in adults using the ANT paradigm developed by Posner and collaborators. This paradigm was chosen because it is believe to tap into three relatively different aspects of attention (alerting, orienting and executive attention). Thus although this aspect of attention is put at a premium during action playing, it is not modified by it. This work demonstrates the high specificity of attentional changes following training.